

1 CLAIMS

- 2
- 3 1. A facial image-processing method comprising:
- 4 illuminating a face with illumination; and
- 5 contemporaneously capturing structure data describing the face's structure
- 6 and reflectance data describing reflectance properties of the face from the
- 7 illumination.
- 8
- 9 2. The method of claim 1, wherein said illuminating comprises using
- 10 multiple light sources.
- 11
- 12 3. The method of claim 2, wherein one of the light sources projects a
- 13 pattern on the face from which the structure data can be ascertained.
- 14
- 15 4. The method of claim 2, wherein one of the light sources comprises an
- 16 infrared light source.
- 17
- 18 5. The method of claim 2, wherein all of the light sources comprise
- 19 infrared light sources.
- 20
- 21 6. The method of claim 1, wherein said illuminating comprises using
- 22 multiple polarized light sources.
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- 24
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1 7. The method of claim 1, wherein said illuminating comprises
2 illuminating the face with light sources at different frequencies.

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4 8. The method of claim 1, wherein said capturing comprises using a
5 camera having a polarizer that suppresses specularly-reflected light so that diffuse
6 component reflection data is captured.

7
8 9. The method of claim 8, wherein one of the light sources projects a
9 pattern on the face from which the structure data can be ascertained.

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11 10. The method of claim 9, wherein the one light source comprises an
12 infrared light source.

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14 11. The method of claim 1, wherein said illuminating comprises
15 illuminating the face with multiple narrow-band light sources.

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17 12. A facial image-processing method comprising:
18 illuminating a face with a first polarized light source that is selected so that
19 specularly-suppressed reflective properties of the face can be ascertained;
20 illuminating the face with a second structured light source that projects a
21 pattern onto the face, while simultaneously illuminating the face with the first
22 polarized light source;
23 capturing both specularly-suppressed reflection data and structure data from
24 the simultaneous illumination.

1 **13.** The method of claim 12, wherein the light sources provide light at
2 different frequencies.

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4 **14.** The method of claim 12, wherein the light sources provide infrared
5 light.

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7 **15.** The method of claim 12 further comprising processing the captured
8 data to provide both (a) data that describes dimensional aspects of the face and (b)
9 data that describes diffuse reflective properties of the face.

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11 **16.** The method of claim 15, wherein the data that describes the diffuse
12 reflective properties of the face comprises an albedo map.

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14 **17.** A facial image-processing method comprising:
15 illuminating a face with multiple different light sources;
16 measuring range map data from said illuminating;
17 measuring image data from said illuminating;
18 deriving a 3-dimensional surface from the range map data;
19 computing surface normals to the 3-dimensional surface; and
20 processing the surface normals and the image data to derive an albedo map.

21
22 **18.** The method of claim 17, wherein at least one of the light sources is
23 polarized.

1 **19.** The method of claim 17, wherein all of the light sources are
2 polarized.
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4 **20.** The method of claim 17 further comprising after said measuring of
5 the range map data, applying a generic face template to the range map data to
6 reject noise that is associated with the range map data.
7

8 **21.** The method of claim 17 further comprising prior to deriving the 3-
9 dimensional surface, filtering the range map data.
10

11 **22.** A facial image-processing method comprising:
12 receiving range map data and image data that are generated from a
13 simultaneous facial illumination;
14 deriving a 3-dimensional surface from the range map data;
15 computing surface normals to the 3-dimensional surface; and
16 processing the surface normals and the image data to derive an albedo map.
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18 **23.** One or more computer-readable media having computer-readable
19 instructions thereon which, when executed by a computer, implement the method
20 of claim 22.
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22 **24.** A facial image processing system comprising:
23 a facial illumination system that is configured to provide multiple different
24 light sources at the same time for illuminating a subject's face; and
25

1 a data-capturing system configured to capture both structure data and
2 reflectance data from the subject's face when illuminated by the facial
3 illumination system.

4
5 **25.** The system of claim 24, wherein the illumination system comprises
6 at least one polarized light source.

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8 **26.** The system of claim 24, wherein the illumination system comprises
9 multiple polarized light sources.

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11 **27.** The system of claim 24, wherein the illumination system comprises
12 a patterned light source configured to project a pattern onto the subject's face.

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14 **28.** The system of claim 27, wherein the patterned light source
15 comprises an infrared light source.

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17 **29.** The system of claim 24, wherein the different light sources are all
18 infrared light sources.

19
20 **30.** The system of claim 24, wherein at least one of the different light
21 sources comprises an infrared light source.

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23 **31.** The system of claim 24, wherein the different light sources are
24 selected to comprise narrow-band light sources.

1 **32.** A facial image processing system comprising:

2 multiple different light sources, one of which providing structured light that

3 can be projected onto the face of a subject, another of which providing light from

4 which specularly-suppressed, diffuse reflectance data from the subject's face can

5 be ascertained;

6 a camera configured to capture structure and reflectance data from an

7 illumination of the subject's face with the multiple different light sources; and

8 a computerized image processor configured to process the structure and

9 reflectance data to provide an albedo map that describes specular-suppressed

10 diffuse reflectance properties of the subject's face and dimensional data that

11 describes dimensional aspects of the subject's face.

12

13 **33.** The system of claim 32, wherein the computerized image processor

14 is configured to:

15 measure range map data;

16 compute a 3-dimensional surface from the range map data;

17 compute surface normals to the 3-dimensional surface; and

18 derive the albedo map from the surface normals and the reflectance data.

19

20 **34.** The system of claim 33, wherein the computerized image processor

21 is configured to filter the range map data prior to deriving the 3-dimensional

22 surface.

1 **35.** The system of claim 34, wherein the computerized image processor
2 filters the range map data by applying a generic face template to the data.
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5 **36.** A facial image processing method comprising:
6 illuminating a subject's head with one or more light sources that are
7 selected to suppress specular reflection;
8 capturing digital images from a plurality of positions around the subject's
9 head while the subject's head is illuminated;
10 computing an albedo map for each of the digital images; and
11 combining two or more of the computed albedo maps for the digital images
12 to provide a single albedo map for the subject's head.
13
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15 **37.** The facial image processing method of claim 36, wherein the light
16 sources provide polarized light.
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19 **38.** The facial image processing method of claim 37, wherein said
20 capturing comprises using a digital camera that has a complementary polarizer
21 configured to remove the specularity.
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24 **39.** The facial image processing method of claim 36, wherein said
25 combining comprises computing a weighted average of individual albedo maps.
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1 **40.** The facial image processing method of claim 39, wherein said
2 computing of the weighted average comprises using a weighting function that
3 gives higher weights to pixels that are viewed and/or illuminated from directions
4 nearly normal to the surface of the subject.

5
6 **41.** The facial image processing method of claim 36, wherein said
7 computing comprises:

8 for each pixel in a texture map:

9 computing a surface normal;

10 computing the irradiance;

11 computing the viewing direction; and

12 computing coordinates in image space; and

13 computing the Lambertian reflectance for one or more of the pixels.

14
15 **42.** The facial image processing method of claim 36, wherein said
16 computing comprises, prior to computing an albedo for a particular pixel,
17 verifying that the pixel is visible and suitably illuminated.

18
19 **43.** The facial image processing method of claim 42 further comprising
20 designating each pixel as having different degrees of visibility and illumination
21 and computing an albedo for a pixel only if the pixel is fully visible, fully
22 illuminated by at least one light source, and not partially illuminated by any light
23 source.

1 **44.** A facial image-processing system comprising:
2 a camera;
3 multiple light sources that produce light selected to suppress the specular
4 reflection of a subject's head that is viewed by the camera; and
5 an image processor configured to:
6 receive multiple digital images of a subject's head that are produced
7 by the camera;
8 compute an albedo map for each image;
9 combine albedo maps for all of the images to provide a single albedo
10 map for the subject's head.

11
12 **45.** The facial image processing system of claim 44, wherein the image
13 processor combines the albedo maps by computing a weighted average of the
14 individual albedo maps.

15
16 **46.** The facial image processing system of claim 45, wherein the image
17 processor computes the weighted average of the individual albedo maps by using a
18 weighting function that gives higher weights to pixels that are viewed and/or
19 illuminated from directions nearly normal to the surface of the subject.